THE EFFECT OF VARIOUS TYPES OF BUILDING ROOF MATERIALS

ON THE COOLING LOAD

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DEDICATION

This thesis is dedicated to my supervisor Professor Ir.Mohammad Zainal Md.Yusof, and to my father and mother, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my sister and wife, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

Roof insulation is one of the most important strategies to reduce the electricity consumption in the building which lead to cost savings and reduce the emission of gases that pollute the environment directly. Therefore, Building information modelling took great interest in recent years in the world in terms of the design simulation of the buildings and choose the best design. This study aimed to evaluate the effect of various types of building roof materials on the cooling load. This study involved in selecting a particular building type (factory building) and the effect of the cooling load by using a various metal deck roofing with and without insulation. Case study in this project is a simple factory building consists of two floors, ground floor is a production space and the first floor is the factory's offices. The cooling load requirement for the building was calculated by using Auto desk Revit software. The results indicated that roof insulation is one of the most important strategies to reduce the cooling load and enhanced the electricity consumption in the building. 20% reduction in the space cooling lead to cost savings and reduce the emission of gases that pollute the environment directly.

ABSTRAK

Penebat bumbung adalah satu daripada strategi penting untuk mengurangkan pengunaan elektrik dalam bangunan yang membolehkan penjimatan kos dan mengurangkan pengeluaran gas yang mencemarkan persekitaran secara terus. Oleh itu, membina informasi model mengambil minat besar pada tahun terkini dari segi rekabentuk simulasi bangunan dan memilih reka bentuk terbaik. Kajian ini bertujuan untuk menilai kesan daripada pelbagai jenis bahan atap bangunan terhadap beban sejuk. kajian ini melibatkan pemilihan sesetengah jenis bangunan(bangunan kilang) dan kesan daripada beban penyejukan mengunakan perbagai jenis bahan lapisan bumbung dengan penebat dan tampa penebat. Projek ini melibatkan bangunan kilang yang mempunyai dua tingkat, tingkat bawah adalah ruang pengeluaran dan tingkat atas adalah pejabat kilang.Beban penyejukan yang diperlukan untuk bangunan dikira mengunakan aplikasi Auto desk Revit. Keputusan menunjukkan penebat bumbung adalah satu strategi yang sangat penting untuk mengurangkan beban penyejuk dan mengurangkan penggunaan elektrik dalam bangunan. 20 % pegurangan pada ruang penyejukan membantu pengurangan kos dan mengurangkan pengeluaran gas yang mencemarka alam sekitar secara terus.

CONTENTS

TITLE	**I**
DEDICATION	**III**
ACKNOWLEDGEMENT	**IV**
ABSTRACT	**V**
LIST OF CONTENTS	**VII**
LIST OF TABLES	**XI**
LIST OF FIGURES	**XIII**
LIST OF SYMBOLELS	**XV**
LIST OF APPENDIX	**XVIII**

CHAPTER 1 INTRODUCTION		**1**
1.1	Introduction	1
1.2	Problem of study	3
1.3	Objectives of study	3
1.4	Scope of study	3
CHAPTER 2 LITERATURE REVIEW		**4**
2.1	Literature review	4
2.2	Introduction	5

2.3	Components of air conditioning system	6
2.4	The roofs effect on the cooling load	7
2.4.1	Roof materials	8
2.4.2	Roof colour	10
2.4.3	The angle of inclination in roof	12
2.4.4	Cool roofs	14
2.5	Applications of air conditioning	16
2.6	Insulation	17
2.6.1	Generic types of insulation	18
2.6.2	Generic forms of insulation	19
2.6.3	Thermal insulation	19
2.6.4	Principles of insulation	20
2.6.4.1	Heat transfer	20
2.6.4.2	Requirements of an insulant	22
2.6.5	Insulation Product selection	22
2.7	Polystyrene foam insulation	25
2.7.1	Optimizing insulation with polystyrene foam	26
2.7.2	Key properties of polystyrene foam	28
2.8	Energy demand of buildings	29
2.8.1	Electricity consumption	30
2.8.2	Air conditioning	31
2.9	Related work	32

CHAPTER 3 METHODLOGY **36**

3.1 Introduction 36

3.2 Flow chart 39

3.3 Methods of estimating cooling loads 40

3.4 Cooling load calculations 41

3.4.1 External loads 42

3.4.1.1 Heat transfer through opaque surfaces 42

3.4.1.2 Heat transfer through fenestration 44

3.4.1.3 Heat transfer due to infiltration and ventilation 45

3.4.2 Internal loads 49

3.4.2.1 Load due to occupants 49

3.4.2.2 Load due to lighting 51

3.4.2.3 Internal loads due to equipment and appliances 52

3.4.3 The total load 54

3.5 Autodesk Revit software 54

3.6 Case study 56

3.6.1 Data 56

3.6.2 Layout 59

3.6.3 Roof and wall layers 60

3.7 Method 62

3.8 Application of Autodesk Revit software 63

3.8.1 Simulation of building model/parameters 64

3.8.2 Setting information 65

CHAPTER 4 RESULTS AND DISCUSSIONS **71**

4.1 Introduction 71

4.2 Building element model 72

4.3 Simulation results 72

4.3.1 Cooling load saving 72

4.3.2 Effect of insulation on roof heat transmission 74

4.3.3 The effect of the cooling load on the electricity consumption with and without insulation 76

4.3.4 Monthly peak demand 79

4.3.5 Cost and saving 80

CHAPTER 5 CONCLUSION **82**

5.1 Introduction 82

5.2 Conclusion of the study 83

5.3 Study contribution 84

5.4 Future works 84

REFERENCES **85**

APPENDIXE **90**

LIST OF TABLES

		PAGE
3.1	Shading coefficients for glass without or with interior shading devices	45 46
3.2	Maximum solar heat gain factor ($SHGF_{max)}$ for sunlit glass, north latitudes	45 46
3.3	Cooling load factor (CLF) for glass with interior shading and location in north latitudes	46 47
3.4	Total heat gain, sensible heat gain fraction from occupants	50 51
3.5	CLF for occupants	51 52
3.6	CLF for lighting	52 53
3.7	Typical appliance load	53 54
3.8	Weather conditions in Batu Pahat city included temperature and huimidty	56 57
3.9	Data for machine and equipment	58 59
3.10	Details for zone 1 (Ground floor) and zone 2 (1^{st}.floor)	68 69
4.1	The building cooling load for roof with and without insulation	74 75
4.2	Cooling load of the roof of the factory building with and without insulation	76 77
4.3	The electricity consumption of the factory building with and without insulation	78 79

LIST OF FIGURES

2.1	Thermal radiation from roof into interior	8
2.2	The angle of inclination in roof	13
2.3	Roof with conventional paint (a) and with cool roof paint (b)	14
2.4	Granular insulation a, cellular insulation b, and fibrous insulation c	18
2.5	Extruded polystyrene foam board (a) and expanded polystyrene foam board (b)	27
2.6	Measured consumption of electricity, heat and water heating in an Office building with passive house standard in Weilheim-Teck, Germany	31
2.7	Cooling energy demand for various sectors in Germany	32
3.1	Difference between instantaneous heat gain and cooling load as a result of heat storage effect	38
3.2	Process flow chart of project	39
3.3	Various components of cooling load	42
3.4	First floor (Administrative Area)	59
3.5	Ground floor (Production Area)	60
3.6	Wall layers	60
3.7	Roof layers	61
3.8	The roof of factory building without the insulating material	62
3.9	The roof of factory building with insulating material	63

3.10	Assembly roof layers	64
3.11	Assembly walls layers	64
3.12	The factory building 3D model	65
3.13	The location of the factory building	66
3.14	Cooling design temperatures	66
3.15	Space setting	67
3.16	Zone setting	67
3.17	Identification of space type	69
3.18	Identification of lighting and power	69
3.19	Identification of number of peoples	70
3.20	Identification of indoor design conditions	70
4.1	Building monthly cooling load with and without insulation	73
4.2	Cooling load of the roof with and without insulation	75
4.3	Monthly electricity consumption with and without insulation	77
4.4	Electricity consumption saving	79
4.5	Monthly peak demand of electricity with and without insulation	80
4.6	Annually Cost and saving of the factory building with and without insulation	81

LIST OF SYMBOLES AND ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning
HVAC	Heating, Ventilation and Air Conditioning
EPS	Expanded Polystyrene
XPS	Extruded Polystyrene
IRMA	Inverted Roof Membrane Assembly
CLTD	Cooling Load Temperature Difference
SHGF	Solar Heat Gain Factor
TFM	Transfer Function Method
U	The overall heat transfer coefficient
A	Area
ΔT	The temperature difference
SHFGmax	The Maximum Solar Heat Gain Factor
SC	Shading Coefficient
CLF	The Cooling Load Factor
m_{inf}	The amount of air infiltration
v	Wind speed m/s
ρ	Air density kg/m3
V	The volume of the space adjuster
Q_{Sleak}	The sensible heat transfer rate due to infiltration and ventilation

Q_{Lleak}	The latent heat transfer rate due to infiltration and ventilation
C_p	Specific heat of the air
m_{iv}	The amount of air ventilation
h_{fg}	Latent heat of vaporization of water at room temperature
w_o,w_i	The outdoor and indoor humidity, respectively
$T_o T_i$	The outdoor and indoor dry bulb temperatures
Q_S	Sensible heat transfer due to the occupants
Q_L	Latent heat transfer due to the occupants

LIST OF APPENDICES

APPENIDEX	TITLE	PAGE
A	Styrofoam Brand Roof mate (Extruded polystyrene foam insulation)	90
B	Steel roof deck considerations	92
C	Euro steel-aluminum sheet	94
D	Energy analysis result (use electricity)	96

CHAPTER 1

INTRODUCTION

1.1 Introduction

Air-conditioning is a process that simultaneously conditions air; distributes it combined with the outdoor air to the conditioned space; and at the same time controls and maintains the required space's temperature, humidity, air movement, air cleanliness, sound level, and pressure differential within predetermined limits for the health and comfort of the occupants, for product processing, or both (Kreith, F. 1998).

Air-conditioning System consists of components or equipment connected in series to control the environmental parameters. An air-conditioning system, by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) definition is a system that must accomplish four objectives simultaneously. These objectives are to control, air temperature, air humidity, air circulation; and air quality. The cooling is typically done using a simple refrigeration cycle, but sometimes evaporation is used, commonly for comfort cooling in buildings and motor vehicles. In construction, a complete system of heating, ventilation and air conditioning is referred to as "HVAC".

Cooling load is the rate of heat which must be removed from the space to maintain a specific space air temperature and moisture content (ASHRAE, 2005). The parameters affecting cooling load calculations are numerous, for example, the outside air temperature, the humidity ratio, the number and activity of people and etc. These parameters are often difficult to precisely define and always intricately interrelated. Many cooling load components vary in magnitude over a wide range during a 24 hr period. These cyclic changes in load components are not often in phase with each other. Each must be analyzed to establish the maximum cooling load for a building or zone. Moreover effects of thermal accumulation also involve in calculating procedure. Therefore various models and assumptions are developed. The estimated results at the specific time of calculation are normally expected and not the exact ones (Tongshoob &Vitooraporn, 2005).

Insulation of building envelopes, both opaque and transparent, is an important strategy for building energy conservation. Insulation of walls, roof, attic, basement walls and even foundations is one of the most essential features of energy efficient homes. In addition, as glass is a poor insulator, insulating transparent envelopes, windows and skylights, significantly reduces heat loss and gain during the winter and summer (Jong et al., 2009).

The insulation strategy of a building needs to be based on a careful consideration of the mode of energy transfer and the direction and intensity in which it moves. This may alter throughout the day and from season to season. It is important to choose an appropriate design, the correct combination of materials and building techniques to suit the particular situation.

1.2 Problem of study

This study focused on reducing the electrical consumption for various environmental condition by optimizing the cooling load of a building. The issue in this research is that of enhancement the cooling performance by mean of using insulator.

1.2 Objectives of study

The objectives of the study are:

1. To calculate the cooling load of a building for various environment conditions.
2. To investigate the effect of using various types of roof material with and without insulator in the building on the cooling load.

1.3 Scope of study

The scopes of study are as follow:

1. Calculate the cooling load of a simulated factory building for 12 months in the district of Batu Pahat, Malaysia by using Autodesk Revit software.
2. Compare the cooling load of the factory building of a particular type of roof with and without roof insulator and the saving in electrical energy.
3. The roof layers consisting of metal deck, polystyrene foam (three thicknesses 1.6, 5 and 10 mm respectively) and aluminum sheet.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Review

This chapter presents an overview of the major concepts related to air conditioning system, cooling load, the effect of roofs insulation on the cooling load and the interactions between them.

2.2 Introduction

Full air conditioning implies the automatic control of an atmospheric environment either for the comfort of human beings or animals or for the proper performance of some industrial or scientific process. The adjective 'full' demands that the purity, movement, temperature and relative humidity of the air be controlled, within the limits imposed by the design specification. For certain applications, the pressure of the air in the environment may also have to be controlled.

Air conditioning is often misused as a term and is loosely and wrongly adopted to describe a system of simple ventilation. It is really correct to talk of air conditioning only when a cooling and dehumidification function is intended, in addition to other aims. This means that air conditioning is always associated with refrigeration and it accounts for the comparatively high cost of air conditioning.

Refrigeration plant is precision-built machinery and is the major item of cost in an air conditioning installation, thus the expense of air conditioning a building is some four times greater than that of only heating it. Full control over relative humidity is not always exercised, hence for this reason a good deal of partial air conditioning is carded out; it is still referred to as air conditioning because it does contain refrigeration plant and is therefore capable of cooling and dehumidifying.

The ability to counter sensible and latent heat gains is, then, the essential feature of an air conditioning system and, by common usage, the term 'air conditioning' means that refrigeration is involved (Jones, 2001).

In modern times the term has been applied to year-round heating, cooling, humidity control, and ventilating required for desired indoor conditions. In other words, air conditioning refer to the control of temperature, moisture content, cleanliness, air quality, and air circulation as required by occupants, a process, or a product in the space. This definition was first proposed by Willis Carrier, an early pioneer in air conditioning (McQuiston, F. C. et al., 2005).

Generally, air conditioning is the process of treating air in an internal environment to establish and maintain required standards of temperature, humidity, cleanliness and motion (Pita, E. G., 2002). These control parameters are:

1. Air Temperature: the temperature is controlled by heating or cooling the air.
2. Air Humidity: the humidity, the water vapor content of the air, is controlled by adding or removing water vapor from the air (humidification or dehumidification).
3. Air Cleanliness: air cleanliness, or air quality, is controlled by either filtration, the

removal of undesirable contaminants using filters or other devices, or by means of ventilation i.e. the introduction of outside air into the space which dilutes the concentration of contaminants. Often both filtration and ventilation are used in an installation.

4. Air Motion: air motion refers to air velocity and to where the air is distributed. It's controlled by appropriate air distributing equipment.

2.3 Components of air conditioning system

Heat always travels from a warmer to a cooler area. In winter, there is a continual heat loss from within a building to the outdoors. If the air in the building is to be maintained at a comfortable temperature, heat must be continually supplied to the air in the rooms. The equipment that furnishes the heat required is called a heating system (Bali, 2005).

In summer, heat continually enters the building from the outside. In order to maintain the room air at a comfortable temperature, this excess heat must be continually removed from the room. The equipment that removes this heat is called a cooling system.

An air conditioning system may provide heating, cooling, or both. Its size and complexity may range from a single space heater or window unit for a small room to a huge system for a building complex.

Most heating and cooling systems have at a minimum the following basic components (Pita, E. G., 2002):

1. A heating source that adds heat to a fluid (air water, or steam)
2. Cooling source that removes heat from a fluid (air or water)
3. A distribution system (a network of ducts or piping) to carry the fluid to the rooms to be heated or cooled.
4. Equipment (fans or pumps) for moving the air or water.

5. Devices (e.g., radiation for transferring heat between the fluid and the room).

2.4 The roofs effect on the cooling load

In tropical countries, including Malaysia, Iraq, which is characterized by its climate heat and long-term drought during the summer season or during the year, the roof ceiling is the most important elements affecting the thermal environment inside buildings because it receives large amounts of solar radiation.

For buildings in equatorial regions with warm and humid climate such as Malaysia, the roof has been said to be a major source of heat gain. Solar protection of the roof remains one of the main concerns in the thermal design of buildings in the region (W. Puangsombut et al., 2007; Francois et al., 2004; Olgyay,1992; Koenigsberger et al., 1980). Previous studies have shown that in Malaysian building, roof has a huge impact on the thermal performance of the whole building (Badrul et al., 2006; Nor, 2005). Due to its geographical location, Malaysia receives the sun directly overhead most of the day throughout the year. Therefore, major heat gain of Malaysian houses comes from the roof. According to previous studies, around 87% of heat transfer from the roof to occupant is through radiation process, whereby only around 13% of heat is transferred through conduction and convection (Cowan, 1973), as illustrated in Figure 2.1 The radiant heat received by the occupants in a space can be measured as mean radiant temperature (MRT).

The mean radiant temperature (MRT) is the area-weighted average of all the surface temperatures in a room, and is affected by the position of the person in relation to the various surfaces. The larger the surface area and the closer to the person, it will have more influence to an occupant's MRT. This explains why the roof plays an important role in determining the overall MRT of the building, which will have a direct impact on the thermal comfort level of the occupants. According to Peng Chen (2002), the thermal radiation of roof largely depends on the composition materials.

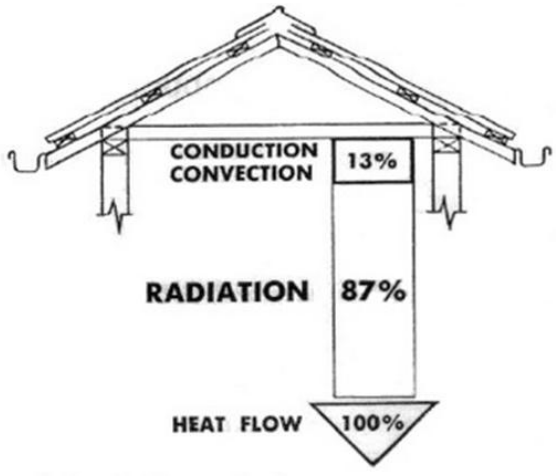

Figure 2.1: Thermal radiation from roof into interior (Cowan, 1973)

The optimization of the thermal performance of the roof can be achieved through different levels of thermal mass, insulation, geometry of ceiling, external colour and levels of ventilation (attic), and roof materials (Madhumathi et al., 2014).

2.4.1 Roof Materials

The heat gain through the outer shell of the structural section of the building consists of a total transmitted amounts of heat in the state of stability (which arise from differing degrees air temperature inside and outside building) and the unstable situation (resulting from variation of solar radiation falling on the roofs of the building density) and complicated heat transfer process through the roof of having heat capacity (whose value depends on both the amount of conductivity makes them part of the stored heat (Thermal, specific heat and density of the components of the roof). (Jones, 1987). Transmitted through it, where the vagaries of the degree of heat to the outer surface of the roof section does not appear rapidly fluctuations .Similar to the degree of the inner surface temperature of the roof section, which means that the construction materials of which the outer roof section will increase of the value of the thermal resistance of the roof itself and thus will increase the amount of delay time to the heat transfer through it, which requires the use of air-conditioning equipment throughout the hours per day to absorb the thermal loads on arrival and reduce the degree of air space temperature to that level specified in advance, which means that the electric power consumption for the purposes of running the air conditioning equipment is linked to the amount of heat transmitted through the roof of the building, reduce that heat will lead to reduce the period of operation of air conditioners and thus reduce the amount of electrical energy consumed for air conditioning purposes.

Warm climatic conditions generally prevail in low altitude areas between 15° north and south latitudes. A significant portion of the global population lives in this region, notably countries in North and South America, Africa, India, Indonesia, Malaysia, Thailand and the Philippines. In this region, the path of the sun generally goes through high altitudes during the daytime, subjecting the roofs of dwellings to intense sunlight. Unlike vertical surfaces such as walls, the roof is exposed to the sun throughout the daytime round the year, significantly contributing to building heat gain (Madhumathi et al., 2014).

The roofing should be tightly fixed and the material should insulate the building from both excessive heat and humidity. Primary requirements for roofing: low thermal capacity (to avoid heat build-up, which cannot be dissipated at night, since there is no temperature drop); resistance to rain penetration, yet permeable enough to absorb moisture and release it when the air is drier; resistance to fungus, insects, rodents and solar radiation; good reflectivity (to reduce heat load and thermal movements); resistance to temperature and moisture fluctuations; freedom from toxic materials (especially if rainwater is collected from roofs).

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